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Weed control by pyrazosulfuron-ethyl and its influence on yield and economics of transplanted rice

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ABSTRACT

A field experiment was conducted on a silty clay loam soil at Palampur, Himachal Pradesh during *Kharif* 2016 and 2017 to assess pyrazosulfuron-ethyl as an alternative herbicide to manage weeds in transplanted rice. Ten treatments comprised of company released sample of pyrazosulfuron-ethyl at 10, 15, 20 and 30 g/ha was compared to its market sample at 10 and 15 g/ha, bispyribac- sodium at 20 and 40 g/ha, hand weeding twice and weedy check. Pyrazosulfuron-ethyl and bispyribac-sodium effectively reduced the biomass of *Echinochloa colona*, *Echinochloa crusgalli* and *Cyperus difformis*. These herbicides also suppressed the growth of *Ammannia baccifera*, but not to the extent as hand weeding twice. Pyrazosulfuron-ethyl curtailed *Eclipta alba*, but lower dose of bispyribac-sodium was not effective against it. In 2016, pyrazsulfuron-ethyl 20 g/ha gave significantly higher yield while in 2017, pyrazsulfuron-ethyl 30 g/ha gave significantly higher yield of rice over other weed control treatments. Every gram weed biomass increase per square metre caused 5.6 kg/ha yield reduction of transplanted rice. Samples of pyrazosulfuron-ethyl obtained directly from the industry had an edge over the market samples. Weed persistence index was found to be decreased and crop resistance index increased corresponding to increase of dose of pyrazosulfuron-ethyl and bispyribac-sodium. The minimum weed index was under company's pyrazosulfuron-ethyl at 20 g/ha followed by 15 g/ha, 30 g/ha and market's sample at 15 g/ha. Cost of weed control was 3.0 to 4.7% of the total cost with pyrazosulfuron-ethyl and 6.1 to 9.8% with bispyribac-sodium. Company procured pyrazosulfuron-ethyl at 15 and 20 g during 2016 and at 20 and 30 g/ha during 2017 had higher net returns and marginal benefit cost ratio (MBCR). Eighty per cent of applied pyrazosulfuron-ethyl got degraded within 5 days of its application. Residues of pyrazosulfuron-ethyl in grain and straw at the time of harvest were below detectable level (BDL) irrespective of treatments.

INTRODUCTION

More than half of rice cultivated in Himachal Pradesh is under low-land transplanted rice while the remaining is either under direct-dry-seeding (upland rice) or wet-seeding (sowing of sprouted seeds onto puddled soil) (Angiras *et al*. 2009). The average productivity of rice in the state (1.8 t/ha) is abysmally low as compared to national rice productivity (2.5 t/ha). One of the major reasons for low productivity is the losses caused due to weeds (Rao *et al.* 2007). Weeds are generally managed either by herbicides or manually and mechanically. However manual weeding is becoming less common because of non-availability of labour at critical times and increased labour cost. Further manual weeding can be performed only when weeds have reached a sufficient size to be pulled out easily by hand. By that time, yield losses may have already occurred. It is, therefore, pertinent to have effective alternatives to manage them.

Use of herbicides has been found promising for managing weeds in different crops. Herbicides are the largest growing segment accounting for about 16% of total crop protection chemicals market (Sharma *et* *al*. 2017). Of a number of herbicides (butachlor, pendimethalin, bispyribac-sodium, cyhalofop-butyl *etc*.) developed and released by the private herbicide manufacturers for efficiently managing weeds in rice crop, pyrazosulfuron-ethyl, which is a sulfonylurea herbicide, was found giving very good control of grassy, broad-leaved and sedges in transplanted as well as direct-seeded rice (Ramesha *et al.* 2017, Saini *et al.* 2008). However, this herbicide need to be tested in elaborate research trials at different ecologies before it is recommended to farmers for adoption. Hence, the present study was undertaken in transplanted rice under mid hill conditions of Himachal Pradesh.

MATERIALS AND METHODS

The field experiment was carried out at Palampur (32^{o}62 N latitude, 76^{o}32 E longitude and 1290.8 m altitude) during *Kharif* 2016 and 2017. The area represents the mid hill sub-humid zone of Himachal Pradesh and is characterized by wet temperate climate. Agro climatically, the experimental site falls under sub-temperate humid zone of Himachal Pradesh, which is characterized by mild summers and cool winters. The area receives a high rainfall that ranges between 1800-2500 mm per annum, of which 80% is received during monsoon months from June to September.

Ten treatments comprising of a private company released samples of pyrazosulfuron-ethyl at 10, 15, 20 and 30 g/ha, market samples of pyrazosulfuron-ethyl at 10 and 15 g/ha, bispyribac-sodium 20 and 40 g/ha, hand weeding twice and weedy check were tested in randomized block design with three replications. Rice variety '*HPR 2143*' was transplanted on 7 July 2016 and 15 July 2017. The crop was fertilized with 90 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha through urea, single super phosphate and muriate of potash, respectively. The required quantity of half N and whole P_2O_5 and K_2O was drilled at sowing. The remaining half N was band placed at 55 DAS. The pyrazosulfuron-ethyl was sprayed 4 days after transplanting (DAT), during both the years, with power sprayer using 600 litres water/ha.

Weed biomass was estimated at 60 DAT, 90 DAT and at harvest by placing 25 × 25 cm quadrats in two spots at random in each plot. These samples were oven dried at a temperature of 70°C till constant weight. Yield attributes and yield were recorded at harvest. Yield was harvested from net plot. Cost of cultivation was worked out by taking together all costs on inputs and operations plus land revenue and interest on working capital. Gross revenue was computed based on the prevalent market prices of the main and by products. Net revenue was obtained by subtracting the cost of cultivation from gross revenue. Net returns per rupee invested was calculated by dividing net returns with cost of cultivation.

The data were subjected to statistical analysis by analysis of variance (ANOVA) for the randomized block design to test the significance of the overall differences among the treatments by the "F" test and conclusion was drawn at 5% probability level. Standard error of mean was calculated in each case. When the 'F' value from analysis of variance tables was found significant, the critical difference was computed to test the significance of the difference between the two treatments. The weed biomass was analysed after subjecting the original data to square root transformation *i.e.* ($\sqrt{x + 0.5}$), and the treatments effects were compared using transformed means.

Impact assessment was carried out after Rana and Kumar (2014). Weed thresholds were worked out as per methods of Stone and Pedigo (1972) and Uygur and Mennan (1995). The soil, plant and grain samples were analyzed for the residues of pyrazosulfuron-ethyl. Pyrazosulfuron-ethyl was extracted with methanol and water. This mixture was subjected to shaking and filtration. The decanted solution was cleaned up in a bed of sodium sulphate using dichloromethane and NaCl. Then washings were concentrated in rotary vacuum evaporator after making the pH of the solution acidic (2.5) using 6N HCl. The residue was re-dissolved in acetonitrile and then subjected to analysis in HPLC equipped with Photo Diode Array Detector.

RESULTS AND DISCUSSION

Effect on weeds

The major weeds of the experimental field were *Echinochloa colona* (accumulated 23.1% and 16.3% of biomass during 2016 and 2017, respectively) and *Echinochloa crusgalli* (12.1% during 2016) among grasses, *Cyperus esculentus* (6.7% during 2017), *Cyperus difformis* (15.9 and 9.2%) and *Cyperus iria* (1.2% during 2016) among sedges and *Ammannia baccifera* (37.7 and 21.7%) and *Eclipta alba* (5.0% during 2017) among broad-leaf.

Weed control treatments brought about significant variation in the biomass of grasses, sedges and broad-leaved weeds (**Table 1**). All weed control treatments were significantly superior to weedy

Table 1. Effect of treatments on biomass (g/m^2) of grasses, sedges and broad-leaved weeds in transplanted rice at 90 DAT

Treatment	Dose (g/ha)	*E.colona*		*E.crusgalli*	*C. diffomis*		*C.iria*	*C.esculentus*	*A. baccifera*		*E.alba*	Total	
		2016	2017	2016	2016	2017	2016	2017	2016	2017	2017	2016	2017
Pyrazosulfuron-ethyl	10	3.3 (10.3)	0.7 (0.0)	2.5 (5.8)	3.1 (9.3)	2.4 (6.9)	1.7 (2.3)	2.5 (5.9)	4.3 (17.7)	4.5 (19.7)	0.7 (0.0)	7.0 (48.8)	6.4 (40.5)
Pyrazosulfuron-ethyl	15	3.3 (10.3)	2.0 (6.4)	2.7 (7.0)	3.2 (9.7)	2.4 (6.9)	1.6 (2.0)	2.1 (5.3)	4.2 (17.0)	3.5 (16.0)	0.7 (0.0)	7.0 (49.0)	5.2 (37.3)
Pyrazosulfuron-ethyl	20	3.0 (8.3)	2.0 (6.9)	2.6 (6.3)	3.1 (9.3)	2.3 (5.9)	1.3 (1.3)	1.9 (3.7)	3.5 (11.7)	3.7 (18.1)	0.7 (0.0)	6.3 (39.0)	5.5 (34.7)
Pyrazosulfuron-ethyl	30	2.7 (7.0)	0.7 (0.0)	2.6 (6.7)	2.3 (4.7)	2.3 (5.9)	0.7 (0.0)	1.9 (3.7)	3.3 (10.3)	3.4 (14.4)	0.7 (0.0)	5.6 (30.7)	4.8 (24.0)
Pyrazosulfuron-ethyl (market sample)	10	3.1 (9.0)	0.7 (0.0)	2.5 (6.1)	3.2 (10.0)	2.6 (8.5)	1.8 (2.7)	2.4 (5.3)	4.3 (17.7)	4.4 (19.2)	0.7 (0.0)	7.0 (48.8)	5.9 (34.7)
Pyrazosulfuron-ethyl (market sample)	15	3.1 (9.0)	0.7 (0.0)	2.5 (6.1)	3.1 (9.0	2.6 (8.5)	1.7 (2.3)	1.8 (3.2)	4.1 (16.3)	4.5 (20.3)	0.7 (0.0)	6.8 (46.4)	6.2 (39.5)
Bispyribac-sodium	20	3.0 (8.3)	0.7 (0.0)	2.5 (6.0)	2.8 (7.3)	2.7 (9.1)	1.5 (1.7)	1.9 (4.3)	3.9 (15.0)	3.6 (17.1)	1.8 (4.8)	6.4 (40.7)	6.3 (40.5)
Bispyribac-sodium	40	2.5 (6.0)	0.7 (0.0)	2.3 (5.1)	2.3 (4.7)	1.6 (3.7)	0.7 (0.0)	1.8 (3.7)	3.3 (10.7)	3.3 (14.4)	0.7 (0.0)	5.3 (27.4)	4.7 (21.9)
Hand weeding twice		1.7 (3.0)	0.7 (0.0)	1.7 (3.0)	1.9 (3.3)	1.3 (2.1)	0.7 (0.0)	1.8 (3.2)	2.3 (6.7)	2.7 (9.1)	1.7 (4.3)	3.9 (17.0)	4.1 (18.7)
Weedy check		4.9 (24.3)	4.0 (20.8)	3.6 (12.7)	4.1 (16.7)	3.0 (11.9)	1.3 (1.3)	3.0 (8.5)	6.3 (39.7)	5.3 (27.7)	2.4 (6.4)	10.2 (105.3)	11.1 (127.5)
LSD (p=0.05)		0.9	NS	0.9	0.5	1.0	0.5	1.8	1.2	1.1	1.1	1.2	2.1

Figures in parentheses are original value

check in curtailing the biomass of grasses, *viz. E. colona* during both the years and *E. crusgalli* during 2016. Hand weeding twice resulted in significantly lower density of all categories of weeds. All weed control treatments controlled *C. difformis* effectively during 2016. However, trends with respect to *C. iria* or *C. esculentus* were not conspicuous. Herbicides pyrazosulfuron-ethyl and bispyribac-sodium also suppressed the growth of *A. baccifera,* but not to the extent as hand weeding. Pyrazosulfuron-ethyl has effectively curtailed *E. alba*, but the lower dose of bispyribac-sodium was ineffective. Hand weeding also was not effective against *E. alba*.

Due to superior reduction of one or the other species, both pyrazosulfuron-ethyl and bispyribac sodium were superior to weedy check in curtailing total weed biomass. Control of weeds increased with increase in the dose of pyrazosulfuron-ethyl, but differences due to doses were not significant as reported by Ramesha *et al.* (2017). Pyrazosulfuron-ethyl gave control of weeds comparable to that with bispyribac-sodium. Manual weeding was better in effectiveness than herbicides except higher doses of pyrazosulfuron-ethyl or bispyribac-sodium during 2017. The effective control of grasses, sedges and broad-leaved weeds with pyrazosulfuron-ethyl (Ramesha *et al.* 2017, Saini *et al.* 2008) and bispyribac-sodium (Kumar and Rana 2013, Kumar *et al.* 2013) in rice has been reported.

Effect on crop

Weed control treatments resulted in significant variation in yield attributes and grain yield of rice (**Table 2**). Due to effective control of weeds, all treatments gave significantly higher yield attributes, *viz.* effective tillers and grains/panicle and yield of transplanted rice over the weedy check. Hand weeding twice (3.25 t/ha) had significantly higher yield at par with other herbicide treatments. Samples of pyrazosulfuron-ethyl obtained directly from the industry had an edge over the market samples. The increase in yield attributes and yield due to effective control of weeds with pyrazosulfuron-ethyl (Ramesha *et al.* 2017, Saini *et al.* 2008) and bispyribac-sodium (Kumar and Rana 2013, Kumar *et al.* 2013) in rice has been reported earlier also. The linear relationship between weed biomass (x) and yield (Y) of transplanted rice is given here as under;

Weed biomass

$Y = 2516 - 5.6x$ (R^2= 0.495)................ (1)

Equation 1 explain over 50% of the variation in transplanted rice yield due to biomass of weeds, could be explained by this regression equation. With every gram weed biomass increase per square metre, the transplanted rice yield was expected to reduce by 5.6 kg/ha.

Table 2. Effect of treatments on yield attributes and yield of rice in 2016 and 2017

Treatment	Dose (g/ha)	Effective tillers (no./m²)		Grains/panicle		1000-grain weight (g)		Rice grain yield (t/ha)	
		2016	2017	2016	2017	2016	2017	2016	2017
Pyrazosulfuron-ethyl	10	330.0	396.0	96.0	94.7	21.7	22.3	1.13	2.96
Pyrazosulfuron-ethyl	15	335.0	407.0	97.3	97.7	23.3	23.7	1.94	3.02
Pyrazosulfuron-ethyl	20	354.2	451.0	99.7	95.7	22.3	23.7	2.00	3.13
Pyrazosulfuron-ethyl	30	346.7	473.0	99.7	99.3	22.3	23.7	1.52	3.19
Pyrazosulfuron-ethyl (market sample)	10	340.0	396.0	99.0	99.0	22.3	23.0	1.63	2.96
Pyrazosulfuron-ethyl (market sample)	15	340.0	407.0	97.3	100.7	21.7	23.0	1.68	2.99
Bispyribac-sodium	20	345.0	385.0	99.7	98.0	22.0	22.7	1.61	2.96
Bispyribac-sodium	40	355.0	451.0	100.0	98.7	22.7	24.0	1.18	3.16
Hand weeding twice	-	360.0	473.0	100.7	101.0	23.0	23.7	1.41	3.25
Weedy check	-	298.3	385.0	88.0	86.7	21.0	22.3	0.93	2.56
LSD (p=0.05)		42.0	52.6	8.5	8.2	NS	NS	0.3	0.3

Table 3. Economic thresholds and impact assessment indices under different treatments (mean of two years)

Treatment	Dose (g /ha)	Gt	Et		WCI	WPI	CRI	WMI	AMI	TEI	WI	W_i
			S&P	U&M								
Pyrazosulfuron-ethyl	10	48	8.5	2.8	61.7	0.60	2.99	1.84	0.84	0.35	12.1	39.0
Pyrazosulfuron-ethyl	15	55	9.8	2.7	63.0	0.61	3.93	2.18	1.18	1.01	-6.4	37.6
Pyrazosulfuron-ethyl	20	62	11.0	2.9	68.4	0.59	4.77	2.08	1.08	1.34	-10.3	34.8
Pyrazosulfuron-ethyl	30	76	13.5	3.8	76.5	0.50	5.72	1.71	0.71	1.31	-1.2	32.0
Pyrazosulfuron-ethyl (market sample)	10	48	8.5	2.4	64.2	0.51	3.69	1.98	0.98	0.76	1.5	41.4
Pyrazosulfuron-ethyl (market sample)	15	55	9.8	2.9	63.1	0.61	3.71	2.05	1.05	0.81	-0.4	37.8
Bispyribac-sodium	20	100	17.8	6.3	60.8	0.65	3.40	2.09	1.09	0.69	1.7	37.6
Bispyribac-sodium	40	167	29.6	9.3	78.8	0.45	5.73	1.53	0.53	0.97	6.8	32.1
Hand weeding twice	-	595	105.7	30.2	84.7	1.05	8.58	1.53	0.53	1.90	0.0	12.8
Weedy check	-	0	0.0	0.0	0.0	1.00	1.00	-	-	0.00	22.6	50.0

Gt, gain threshold, Et, economic threshold; S&P, after Stone and Pedigo; UM, after Uygur and Mennan; WCI, Weed control index (%); WPI, Weed persistence index; CRI, Crop resistance index; WMI, Weed management index; AMI, Agronomic management index; TEI, Treatment efficiency index; WI, Weed index; W_i , Weed intensity

Economic threshold

The economic threshold levels *i.e.* g/m² with the weed management practices varied between 8.5–105.7 g/m² when determined by Stone and Pedigo (1972) and 2.4 to 30.2 g/m² by Uygur and Mennan (1995) (**Table 3**). It is indicated that any increase in cost of weed control would lead to higher values of economic threshold, whereas an increase in price of crop produce would result in lowering the economic threshold. Hand weeding had higher values of economic threshold than the herbicidal treatments due to higher wages. Herbicidal treatments had lower application cost and thus had lower values of economic threshold. Among the treatments, market sample of pyrazosulfuron-ethyl at 10 g/ha had lowest values of economic threshold under both the methods of determination.

Impact assessment

Weed control index (WCI) increased with increase in dose of herbicides (**Table 3**). However, hand weeding treatment had higher weed control index due to frequent removal by hands followed by bispyribac-sodium at 40 g/ha and company sample of pyrazosulfuron-ethyl at 30 g/ha. All herbicide treatments had lower weed persistence index (WPI) than manual weeding. Weed persistence index was found to decrease as the dose of pyrazosulfuron-ethyl or bispyribac sodium increased. The crop resistance index (CRI) increased as the dose of each of pyrazosulfuron-ethyl and bispyribac-sodium increased. However, hand weeding had more crop resistance index (8.58) than all herbicidal treatments due to more weed control index.

Company sample of pyrazosulfuron-ethyl at 15 g/ha had highest weed management index followed by bispyribac-sodium at 20 g/ha, company sample of pyrazosulfuron-ethyl 20 g/ha and market sample of pyrazosulfuron-ethyl at 15 g/ha. Treatment efficiency index (TEI), which indicates weed killing potential and phytotoxicity on the crop, was higher under manual weeding followed by company's

Table 4. The cost of weed control, cost of cultivation (COC) and MBCR as influenced by weed control treatments

Treatment	Dose (g/ha)	Cost of weed control (`/ha)	Gross returns (x10^3 `/ha)		COC (x10^3 `/ha)		Gross return over weedy check (x10^3 `/ha)		Cost of weed control (x10^3 `/ha)		Net return due to weed control (x10^3 `/ha)		MBCR	
			2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Pyrazosulfuron-ethyl	10	960	32.2	72.7	29.9	33.2	5.8	9.2	1.3	1.6	4.5	7.6	3.40	4.71
Pyrazosulfuron-ethyl	15	1100	55.2	74.2	31.2	33.4	28.8	10.7	2.7	1.9	26.1	8.8	9.60	4.76
Pyrazosulfuron-ethyl	20	1240	57.0	76.9	31.5	33.7	30.6	13.5	3.0	2.2	27.6	11.3	9.34	5.18
Pyrazosulfuron-ethyl	30	1520	43.3	78.3	31.0	34.1	16.9	14.9	2.5	2.6	14.4	12.3	5.73	4.78
Pyrazosulfuron-ethyl (market sample)	10	960	46.3	72.6	30.6	33.2	19.9	9.2	2.1	1.6	17.8	7.5	8.54	4.65
Pyrazosulfuron-ethyl (market sample)	15	1100	48.0	73.9	30.9	33.3	21.6	10.4	2.3	1.8	19.2	8.6	8.28	4.75
Bispyribac-sodium	20	2008	46.0	73.1	31.7	34.3	19.6	9.7	3.2	2.7	16.4	6.9	5.17	2.55
Bispyribac-sodium	40	3336	33.6	77.6	32.4	36.0	7.2	14.2	3.9	4.4	3.3	9.7	0.85	2.20
Hand weeding twice	-	11900	40.1	79.6	41.8	45.1	13.7	16.2	13.2	13.6	0.5	2.6	0.04	0.19
Weedy check	-	0	26.4	63.4	28.5	31.5	-	-	-	-	-	-	-	0
LSD (p=0.05)			8.2	5.8	0.4	0.4	-		-	-	-	-	-	-

Table 5. Residues (µg/g) of pyrazosulfuron-ethyl in soil (*Kharif* 2017)

Treatment	Days after herbicide application						
	0	1	3	5	7	10	Harvest
Pyrazosulfuron-ethyl 10 g/ha (3 DAT)	0.179	0.120	0.079	0.046	BDL	BDL	BDL
Pyrazosulfuron-ethyl 15 g/ha (3 DAT)	0.194	0.131	0.107	0.056	BDL	BDL	BDL
Pyrazosulfuron-ethyl 20 g/ha (3 DAT)	0.242	0.148	0.114	0.061	BDL	BDL	BDL
Pyrazosulfuron-ethyl 30 g/ha (3 DAT)	0.297	0.191	0.127	0.069	BDL	BDL	BDL

BDL: Below Detectable level

pyrazosulfuron-ethyl 20 g/ha and 30 g/ha. Weed index (WI) is the measure of the efficiency of a treatment relative to weed free (hand weeding in the present case) indirectly indicating per cent yield reduction. It was highest under weed free. The value indicating 22.6% loss in grain yield of rice due to uncontrolled growth of weeds. The minimum weed index was under company's pyrazosulfuron-ethyl at 20 g/ha followed by 15 g/ha, 30 g/ha and market's sample at 15 g/ha. Hand weeding had the lowest weed intensity and weedy check had the highest.

Cost of weed control was 3.0 to 4.7% of the total cost due to pyrazosulfuron-ethyl and 6.1 to 9.8% with bispyribac-sodium. While that with hand weeding, weed control component had a major share of 27.4% of the total cost of production indicating that controlling weeds with manual methods is a costly proposition. Company procured pyrazo-sulfuron-ethyl at 15-20 g/ha during the first year and at 15-30 g/ha during second year, bispyribac-sodium 20-40 g/ha and hand weeding all during the second year resulted in higher gross returns due to weed control. But due to higher cost of labour, hand weeding resulted in lower net returns over weedy check than all the herbicidal treatments. Company procured pyrazosulfuron at 15-20 g during 2016 and at 20-30 g/ha during 2017 had higher net returns and marginal benefit cost ratio (MBCR).

Residual effects

A progressive decline in pyrazosulfuron-ethyl residue content in soil was observed with advancement of crop growth. Nearly 80% of applied pyrazosulfuron-ethyl got degraded within 5 days of its application and it was found below detectable level on 7th day and at harvest also (**Table 5**). Janaki *et al.* (2015) categorized pyrazosulfuron-ethyl under the herbicides those persist for 1-3 months. There was great influence of different doses of pyrazosulfuron-ethyl on the population of total bacteria, fungi and actinomycetes initially after 3 days of its application (6 DAT) (Kumar *et al.* 2018). Pyrazosulfuron-ethyl at 30 g/ha resulted in maximum reduction of 20.86, 26.39 and 14.12%, respectively, in bacterial, fungal and actionmycetes population. The population of microorganisms under observation was recovered from herbicide shock on 15 days after their spray. Residues of pyrazosulfuron-ethyl in grain and straw at the time of harvest were below detectable level irrespective of treatments.

The findings of the present investigation clearly indicated the effectiveness of pyrazosulfuron-ethyl as good as the standard herbicide bispyribac-sodium in reducing the biomass of weeds and increasing yield attributes and yield of rice.

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